Sources of greenhouse gases and carbon monoxide in central London (UK).

Carole Helfter[1], Anja Tremper[2], Giulia Zazzeri[3], Simone Kotthaus[4], Janet Barlow[4], Sue Grimmond[4] and Eiko Nemitz[1].

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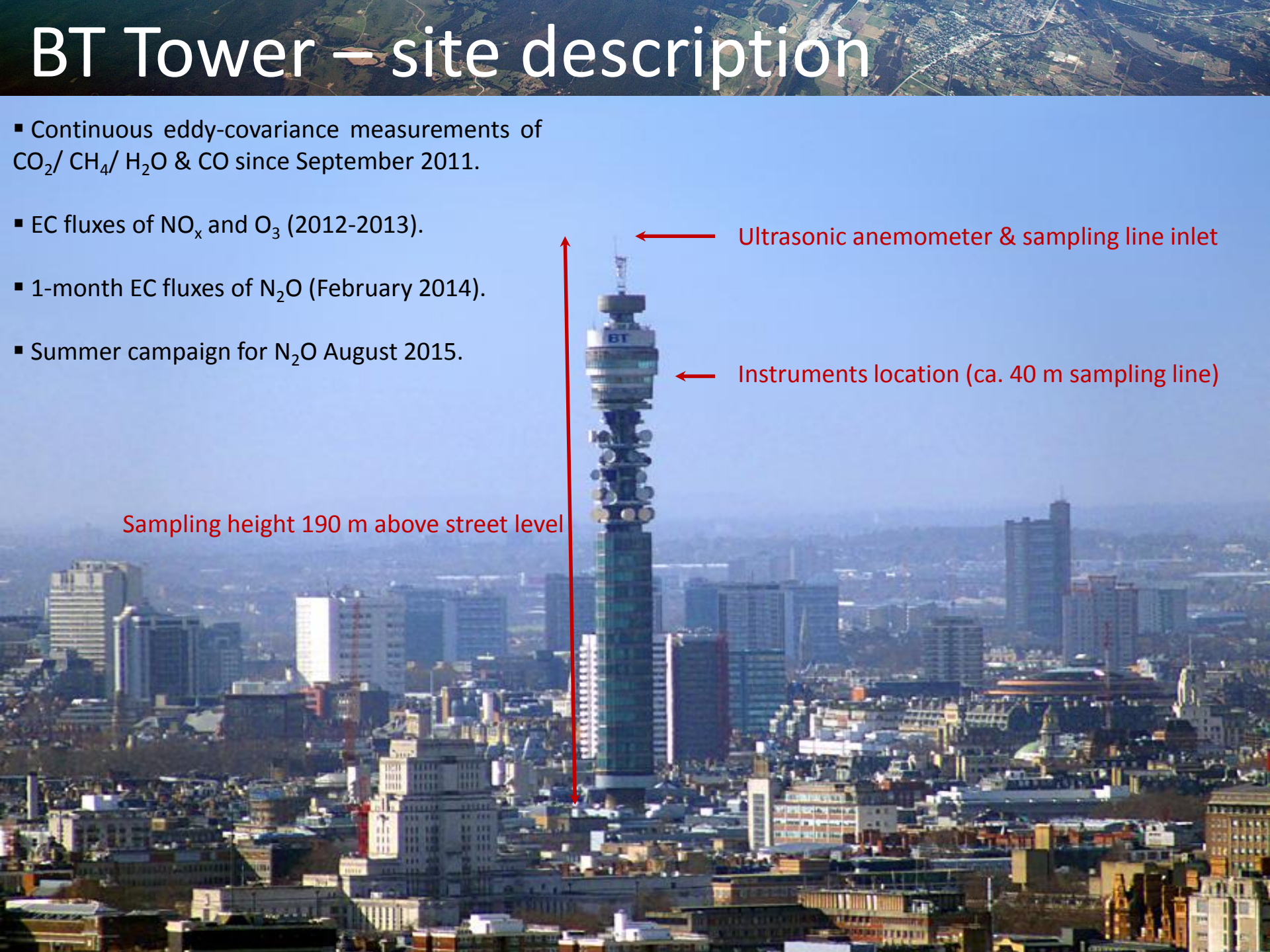
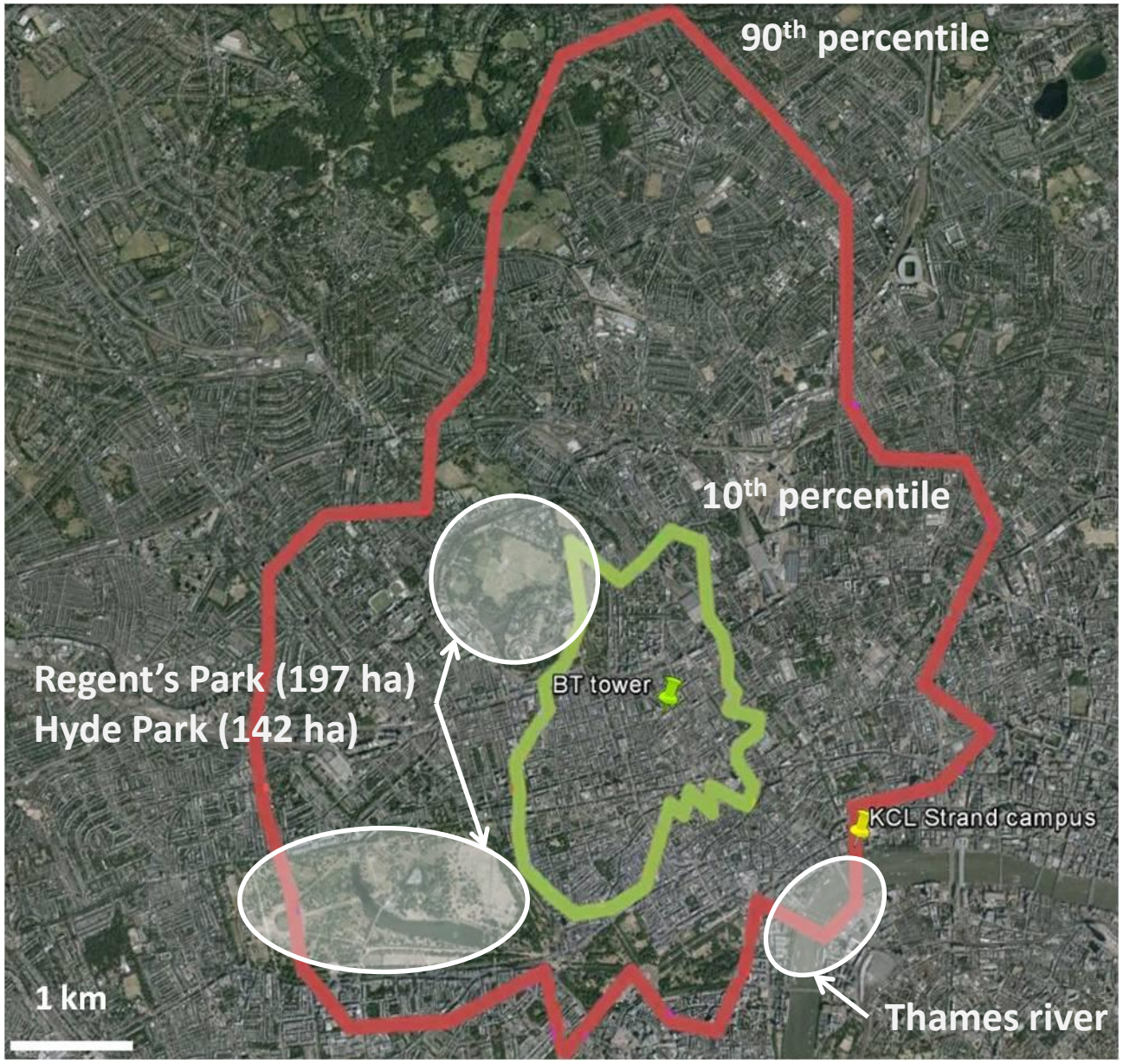
[4] Department of Meteorology, University of Reading, Reading, UK.

BT Tower – site description

- Continuous eddy-covariance measurements of CO_2/ CH_4/ H_2O & CO since September 2011.
- EC fluxes of NO_x and O_3 (2012-2013).
- 1-month EC fluxes of N_2O (February 2014).
- Summer campaign for N_2O August 2015.



BT tower: flux footprint (2012 – 2014)



- Central location.
- Footprint 180 km^2.
- Mean building height 12 m within footprint.
- Typically 2-4 km from the tower (6 km to North).
- N-NW: Mainly residential.
- E & W: gradient commercial – residential.
- SE – SW: heavily built-up, commercial.
- Footprint entrains Thames river SE of tower.

Kormann-Meixner footprint model (2001).

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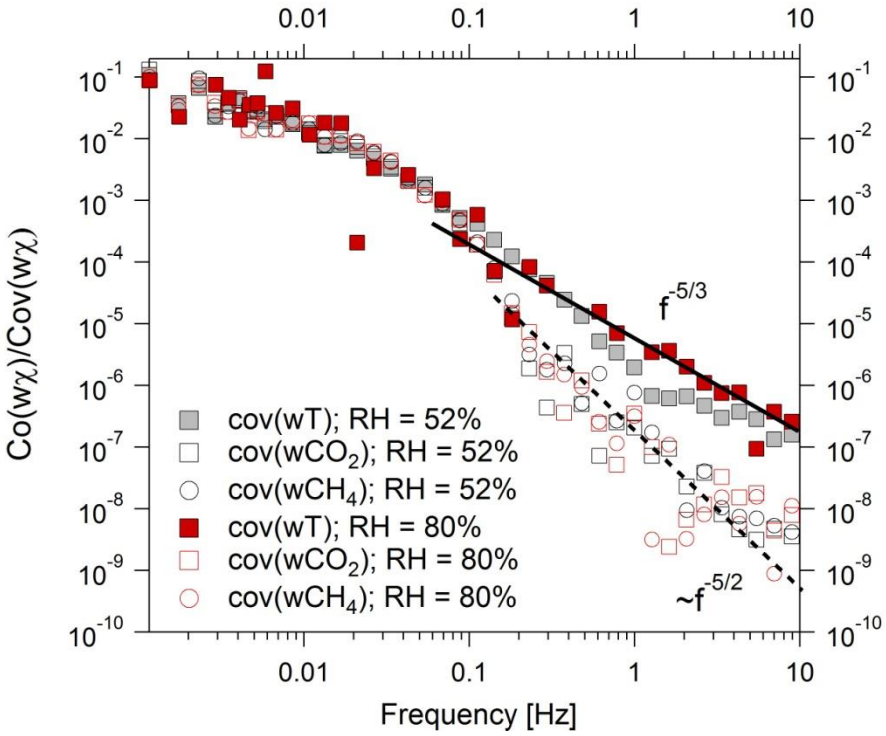
Effect of sampling frequency on fluxes



Normalised cospectra of T (sonic temperature), CO_2 and CH_4 with respect to w (vertical wind component) for low and high relative humidity (grey and red symbols, respectively). Each cospectrum is an average of 24 half-hourly cospectra. Low relative humidity data 12/03/2013 (7:00 – 18:00) and high relative humidity data 15/03/2013 (7:00 – 18:00).

- Ultrasonic anemometer sampling at 20 Hz.
- Picarro G2301-f sampling at 1 Hz.
- Ca. 40 m-long ½'' sampling line (20 lpm).

- Co(wT) follows theoretical slope ($f^{-5/3}$).

- $Co(wCO_2)$ and $Co(wCH_4)$ diverge from theoretical trend for frequencies > 0.2 Hz.

- RH has no/little effect on frequency response.

- Net damping of ~ 20% over frequency range.

- Large eddies.

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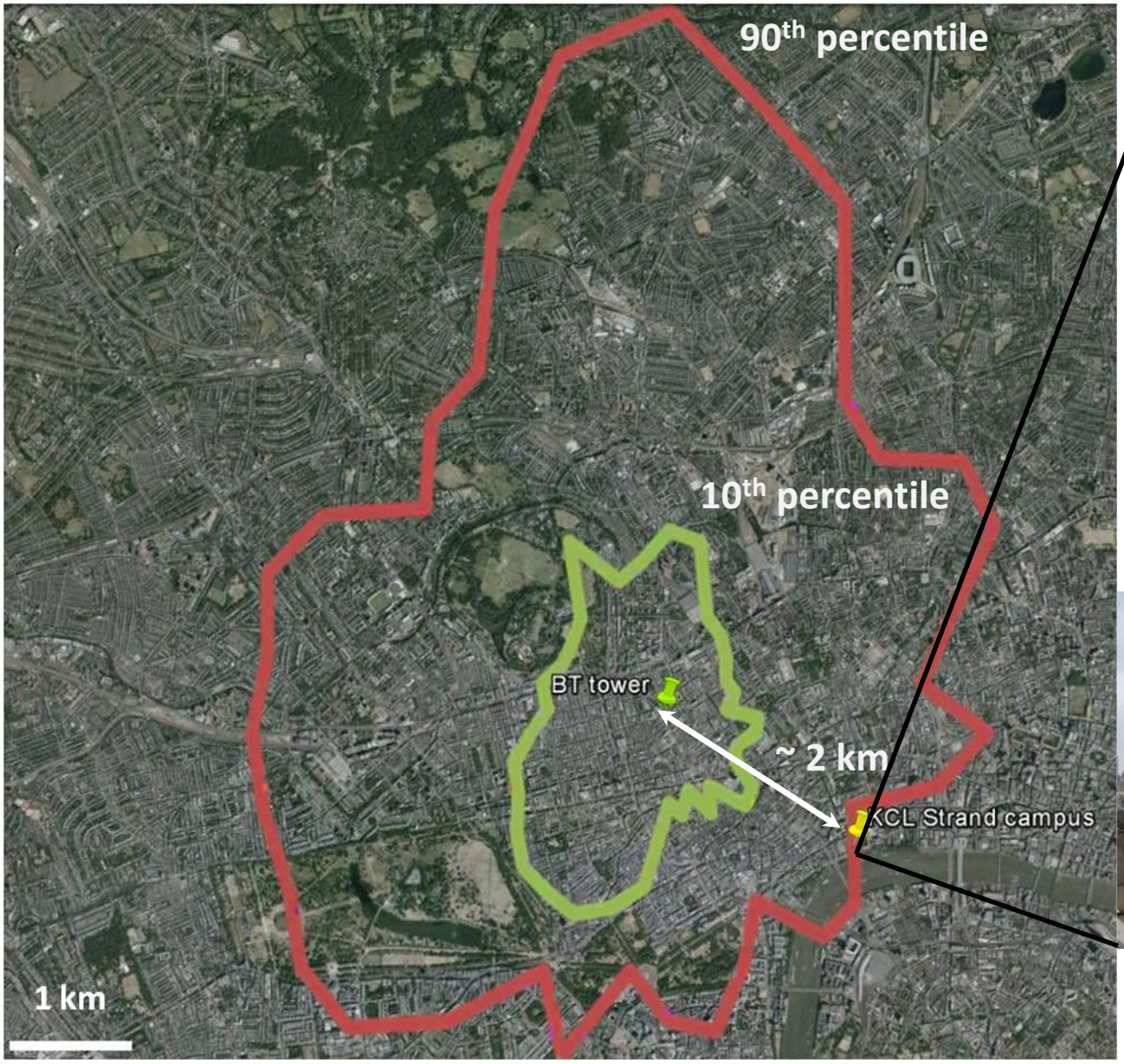
Comparison with rooftop measurements



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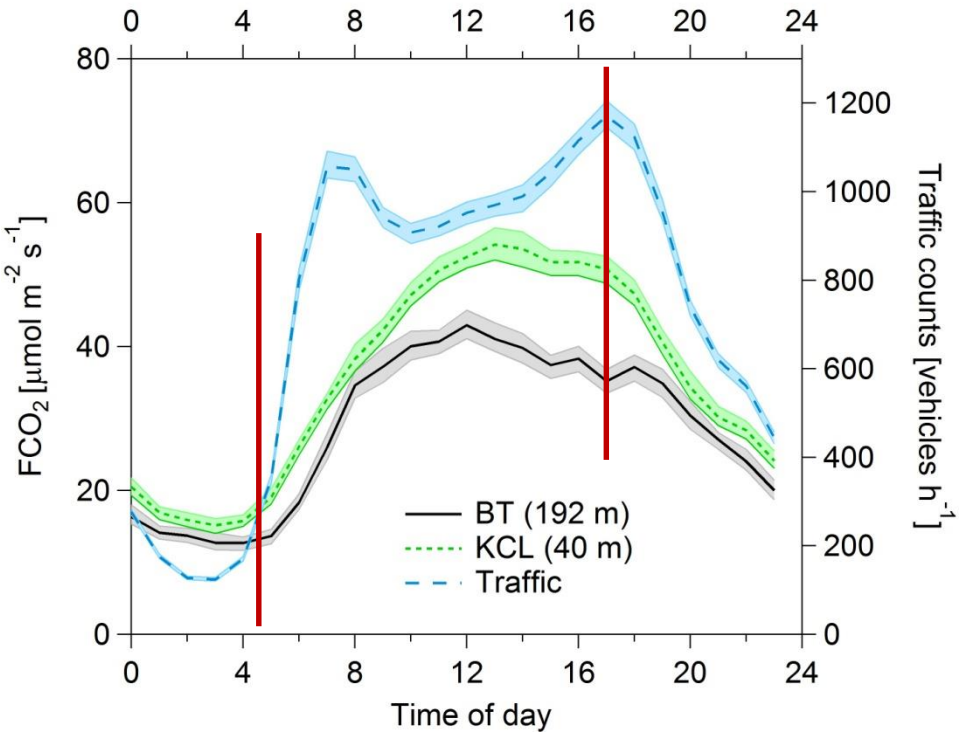
Comparison with rooftop measurements

$FCO2_{KCL}$ 27% ± 11% > $FCO2_{BT}$ between 8:00 and 18:00 (maximum discrepancy of 44% at 17:00).



- Emissions increase from ca. 05:00 at both sites consistent with traffic counts.
- Decrease from ca. 17-18:00.

Temporal dynamics of fluxes measured at tall tower not greatly affect by vertical transport

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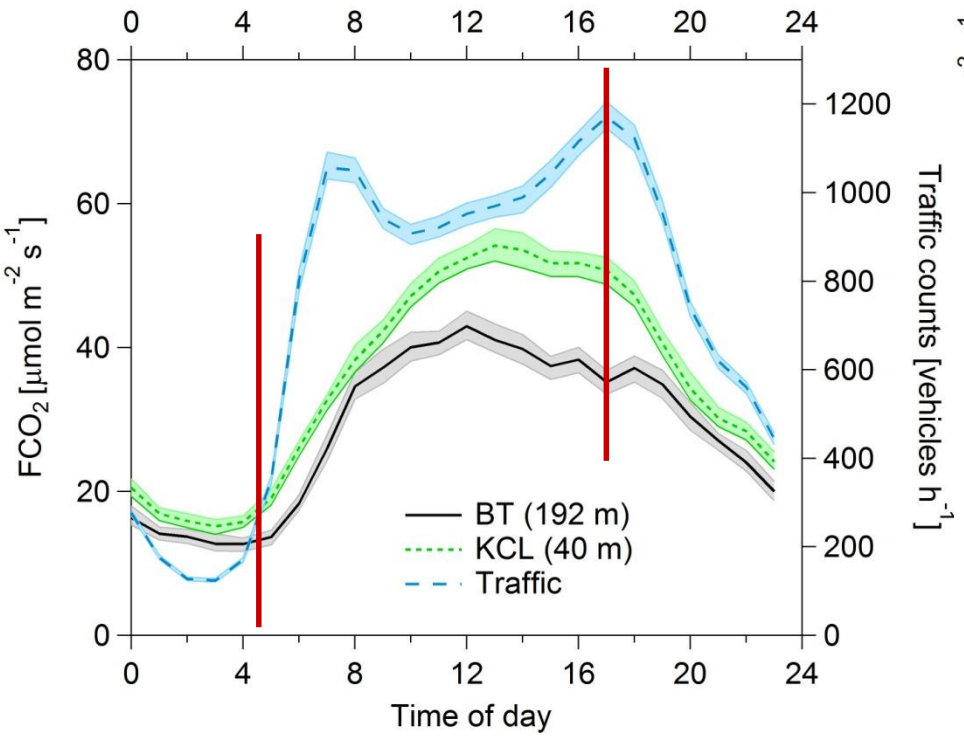

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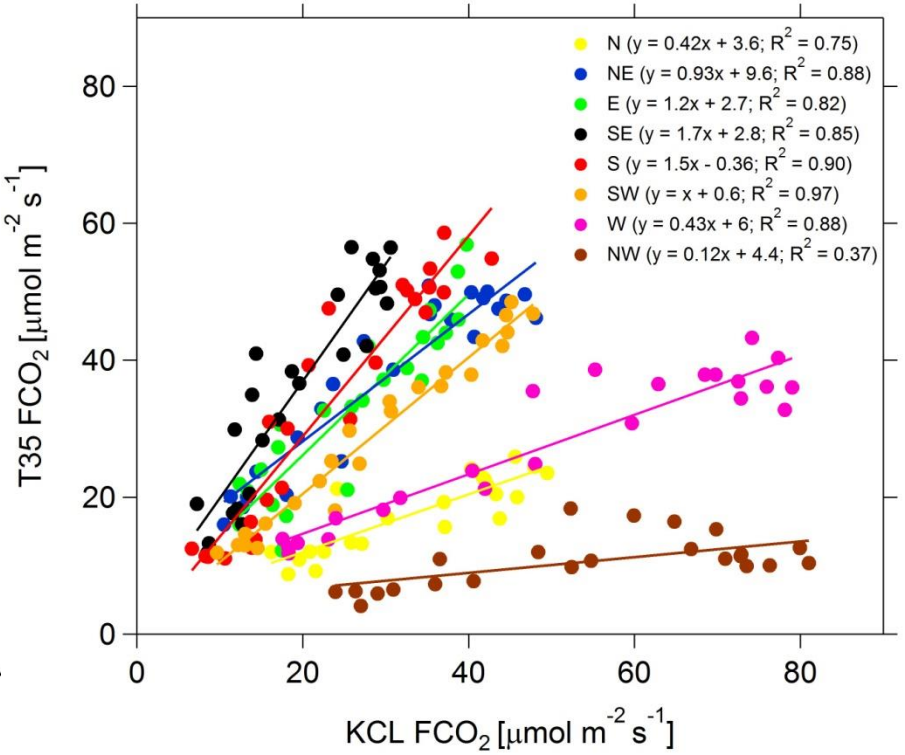
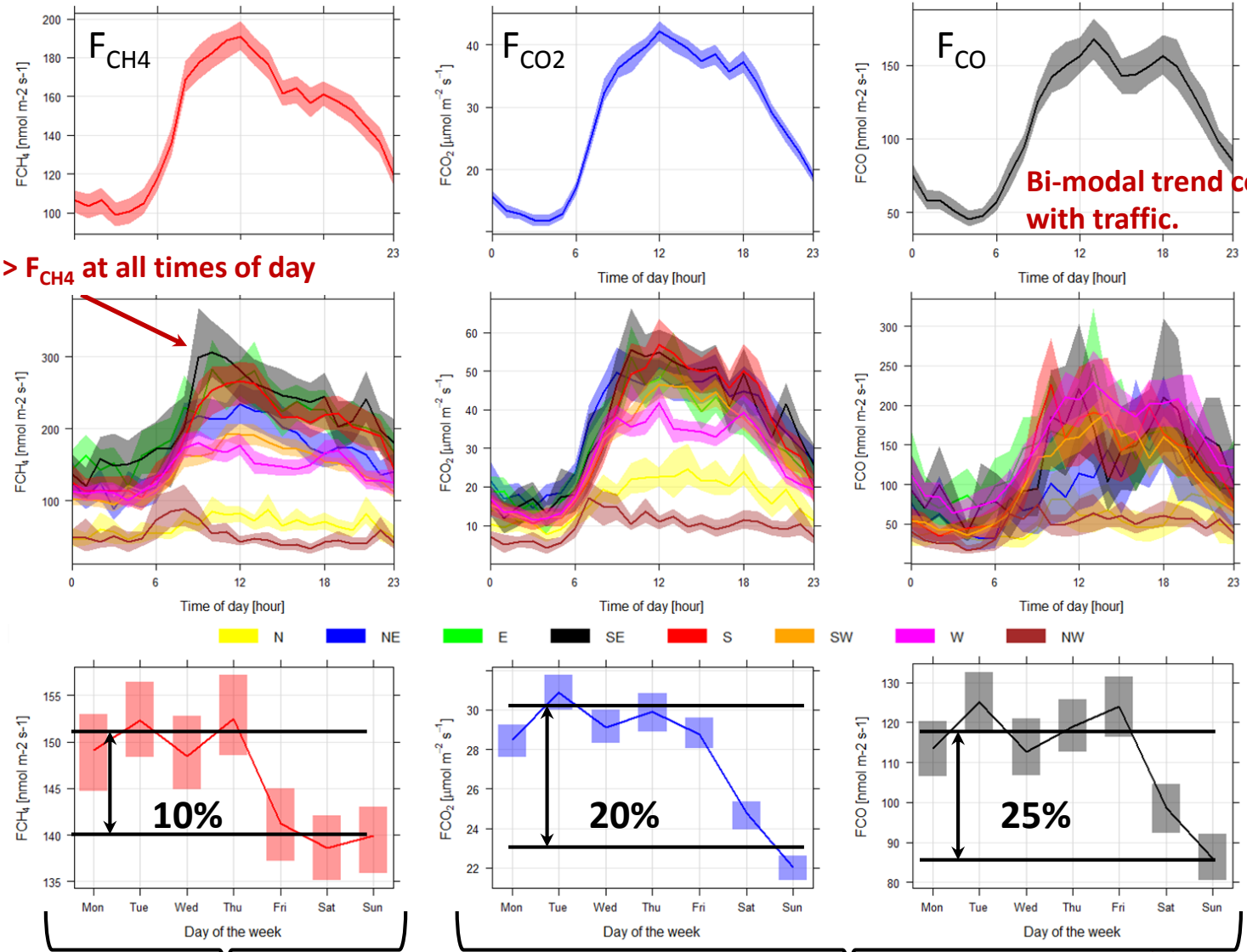


- Magnitude of CO_2 fluxes depends on wind direction.
- Linear correlation between BT and KCL for all wind directions.
- Ratio BT/FCL F_{CO2} in range 0.12 to 1.7.
- Linearity suggest similar temporal emission patterns with different anthropogenic source strengths (different flux footprints.).

Temporal trends



F_{CH4} from SE > F_{CH4} at all times of day

Bi-modal trend consistent with traffic.

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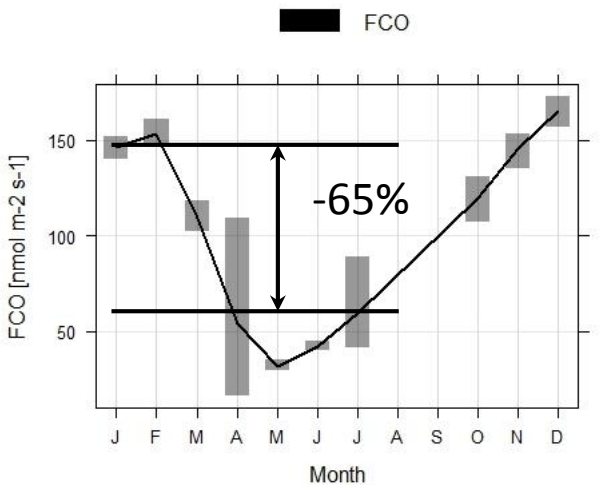
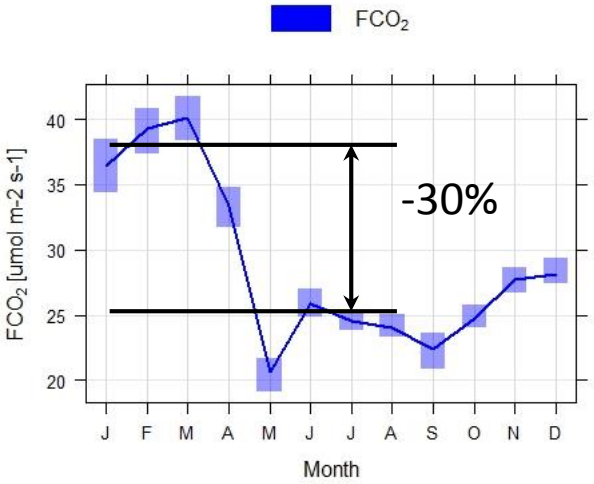
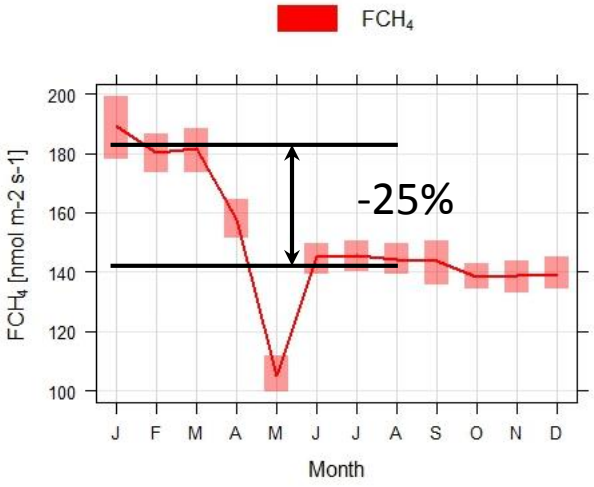
Reduction in natural gas usage

Reduction in traffic and natural gas usage

Seasonal trends

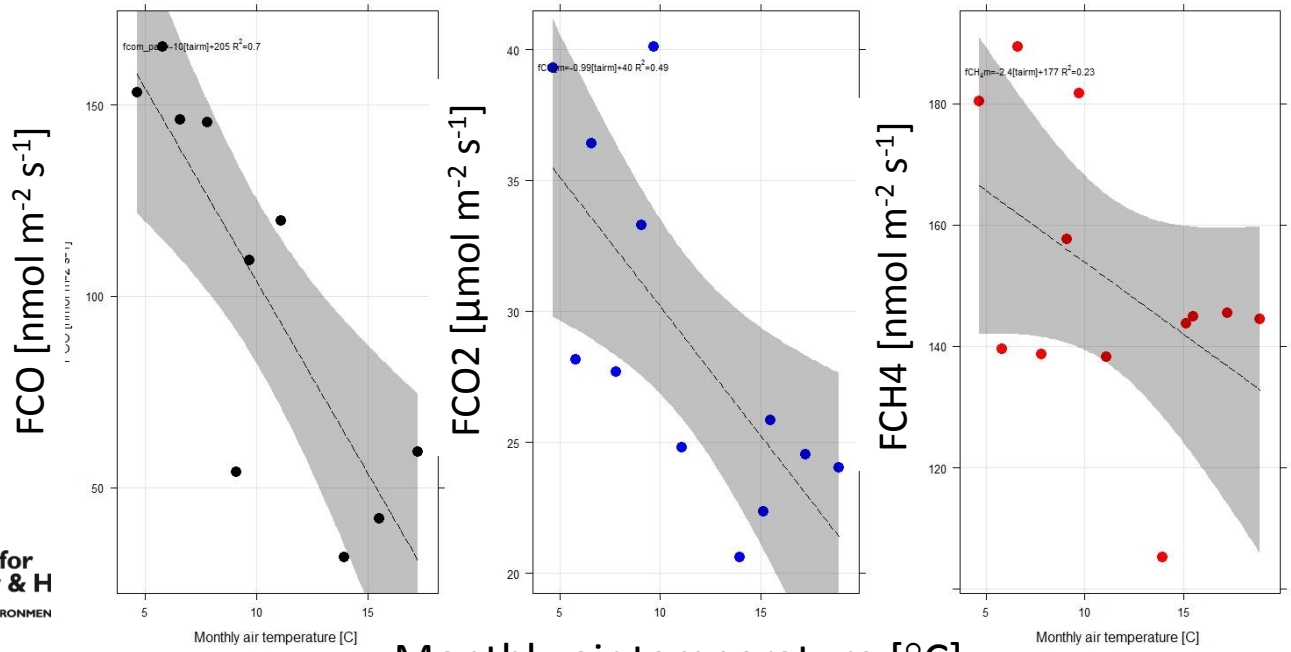






Strong temperature dependence: cold starts?

Reduction in heating (summer) + seasonal variation in traffic.



Monthly air temperature [°C]

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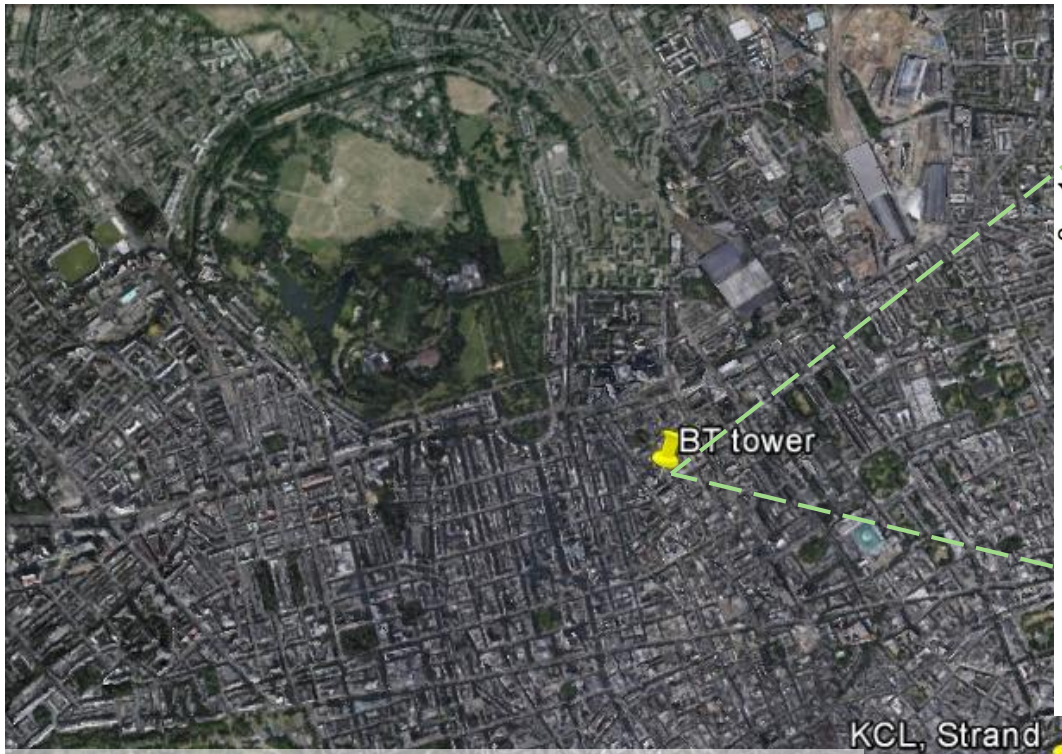
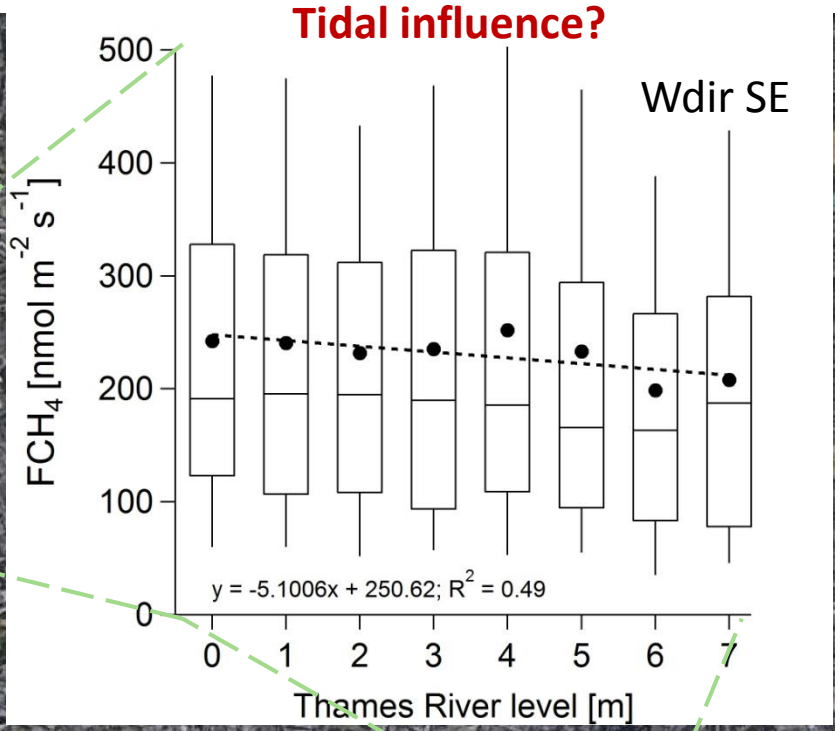
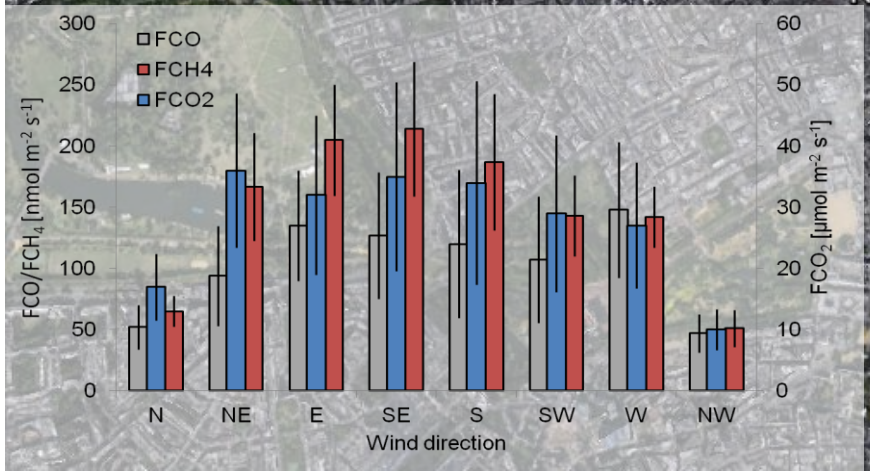
Spatial trends







Isotopic signatures of urban CH_4

- Lighter isotopic source signatures from the SE Sector
- Elevated fluxes of CH_4 measured by EC at the BT tower in SE sector.
- **Methane emissions from the Thames River?**
- **Tidal influence?**

Frequency of counts by wind direction (%)

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BT tower – annual GHG budgets

	CO_2 [tons km^{-2}]	CH_4 [tons km^{-2}]	CO [tons km^{-2}]	N_2O [tons km^{-2}]
Measured at BT tower[1]	41000	75 **(CO_2e 1875)**	156	0.36 **(CO_2e 107)**
Westminster (LAEI)[2]	46000	34	145	0.42
London aircraft measurements (July 2012)[3]	29000	66	106	
London (Autumn 2007 & 2008)[4]			150 to 220	

mol mol^{-1}	CH_4/CO_2	N_2O/CO_2	N_2O/CH_4	CO/CO_2
BT tower measurements	$4.5\ 10^{-3}$	$1.1\ 10^{-5}$	$3.0\ 10^{-3}$	$2.0\ 10^{-3}$
LAEI	$2.1\ 10^{-3}$	$9.2\ 10^{-6}$	$4.3\ 10^{-3}$	$1.9\ 10^{-3}$

[1] *Measured 2012 data (February 2014 for N_2O)*
[2] *London Atmospheric Emissions Inventory (LAEI), 2012 data*
[3] *O'Shea et al. (2014), Journal of Geophysical Research*
[4] *Harrison (2012), Atmospheric Chemistry and Physics*

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Summary

- Dynamic system exhibiting temporal and spatial patterns.
- Annual budgets for the FCO_2, FCO & FN_2O gas in reasonable agreement with atmospheric inventory. Measured FCH_4 is 2x larger than inventory value.
- Is atmospheric inventory underestimating a source of CH_4?
- Isotopic analysis of urban CH_4 identified biogenic source in SE wind direction & EC fluxes larger in SE: possible emissions from Thames river unaccounted for in atmospheric inventories.